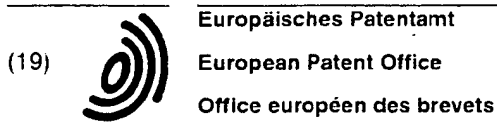


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(54) **Automatic audio equalising system**

(57) An automated process for equalizing an audio system and an apparatus for implementing the process. An audio system includes a microphone unit, for receiving the sound waves radiated from a plurality of speakers, acoustic measuring circuitry, for providing frequency response measurement signals; a memory, for storing characteristic data signals representative of the loudspeaker units and further for storing the frequency response measurement signals; and equalization calculation circuitry, for providing an equalization pattern signal responsive to the frequency response measurement signals and responsive to the characteristic data signals representative of the plurality of loudspeaker units. Also described is an automated equalizing system including acoustic measuring circuitry including a microphone for providing frequency signals representative of responses at a plurality of locations; a memory, for storing the signals representative of frequency responses at the plurality of locations; and equalization calculation circuitry responsive to the signals representative of the frequency responses for providing an equalization pattern signal.

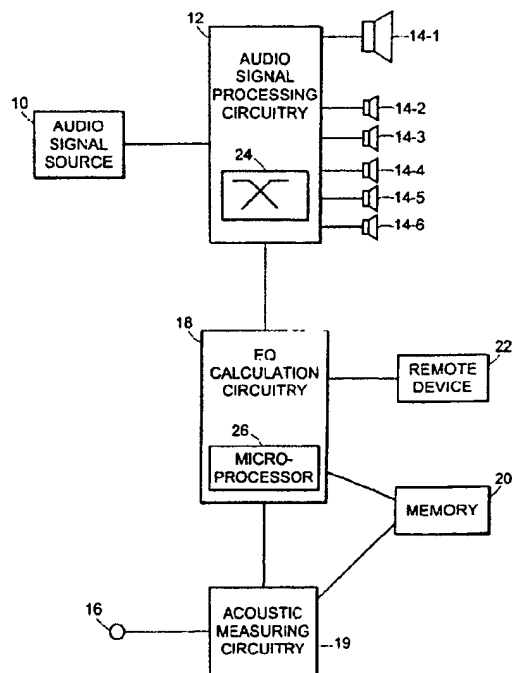


FIG. 1

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Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to equalizing system for audio systems, and more particularly to automated equalizing systems for audio systems.

[0002] It is an important object of the invention to provide an improved equalizing system for audio systems.

BRIEF SUMMARY OF THE INVENTION

[0003] According to the invention, an audio system includes a source of audio signals; signal processing circuitry coupled to the source for processing the audio signals to produce processed audio signals; a plurality of loudspeaker units, coupled to the signal processing circuitry, constructed and arranged to be deployed about a room, for radiating sound waves responsive to the processed audio signals; a microphone unit, for receiving the sound waves and for transducing the sound waves to electrical signals; acoustic measuring circuitry, for receiving the transduced sound waves and furnishing frequency response signals; a memory, coupled to the acoustic measuring circuitry, for storing loudspeaker signals characteristic of the loudspeaker units and further for storing the frequency response signals; and equalization determining circuitry, coupled to the memory, for providing an equalization pattern signal responsive to the stored loudspeaker and frequency response signals.

[0004] In another aspect of the invention, an audio system, includes a source of audio signals; signal processing circuitry coupled to the source for processing the audio signals to produce processed audio signals; a plurality of loudspeaker units, coupled to the signal processing circuitry, constructed and arranged to be deployed about a room, for radiating sound waves responsive to the processed audio signals; acoustic measuring circuitry, including a microphone, for receiving the sound waves and measuring frequency response at a plurality of locations; a memory, coupled to the acoustic measuring circuitry, for storing frequency response signals representation of the frequency response at the plurality of locations; and equalization circuitry, responsive to the stored frequency response signal for furnishing equalization related to the acoustic properties of the room.

[0005] In another aspect of the invention, an audio system includes a source of audio signals, signal processing circuitry coupled to the source for processing the audio signals to produce processed audio signals, a plurality of loudspeaker units, coupled to the signal processing circuitry, constructed and arranged to be deployed about a room, for radiating sound waves responsive to the processed audio signals. An equalizing system for the audio system includes acoustic measuring circuitry, including a microphone, for receiving and

transducing the sound waves and for providing frequency response signals representative of the frequency response at a plurality of locations; a memory, coupled to the acoustic measuring circuitry, for storing the frequency response signals; and equalization circuitry, responsive to the frequency response signals, for furnishing equalization related to the acoustic properties of the room.

[0006] In another aspect of the invention, an audio system, includes a storage medium for storing digitally encoded information signals; signal processing circuitry coupled to the storage medium to produce audio signals; a plurality of loudspeaker units, coupled to the signal processing circuitry, constructed and arranged to be deployed about a room, for radiating sound waves responsive to the audio signals; a microphone unit, for receiving the sound waves and transducing the sound waves to electrical signals; and a microprocessor electronically coupled to the storage medium and to the microphone, for developing an equalization pattern responsive to the electrical signals.

[0007] In another aspect of the invention, a process for generating an equalization pattern in an audio system having a first microphone and a loudspeaker unit, includes testing, by the audio system, the microphone to determine if the microphone is functional over a frequency range; and in the event the microphone is not functional over the frequency range, generating a message to a user.

[0008] In another aspect of the invention, a process for generating an equalization pattern in an audio system operating in a listening area, the listening area having an ambient noise level, the process includes radiating a sound at an amplitude into the listening area; measuring, by the audio system, the signal to noise ratio in the listening area; and in the event that the signal to noise ratio is below a threshold ratio, increasing the signal to noise ratio.

[0009] In another aspect of the invention, a process for generating an equalization pattern in an audio system having a loudspeaker device and a microphone, includes radiating, by the loudspeaker device a sound wave; receiving, by a microphone, the sound wave; measuring the amplitude of the received sound wave to determine if the amplitude is within a predetermined range of amplitudes; and in the event that the amplitude is not within the predetermined range of amplitudes, changing the amplitude so that the amplitude is within the predetermined range.

[0010] In another aspect of the invention, a process for generating an equalization pattern for an audio system having a loudspeaker device and a microphone, the audio system operating in a listening space, includes a first positioning the microphone at a first location; a first radiating, by the loudspeaker device, of a sound wave; a first receiving, by the microphone, of the sound wave; responsive to the receiving, a first measuring of a first frequency response of the audio system; a second po-

sitioning the microphone at a second location; a second radiating, by the loudspeaker device, a sound wave; a second receiving, by the microphone the sound wave; responsive to the second receiving, a second measuring of a second frequency response of the audio system; comparing the first frequency response with the second frequency response to determine the difference between the first frequency response and the second frequency response; and in the event that the difference is less than a predetermined amount, generating a message.

[0011] In another aspect of the invention, a process for generating an equalization pattern for an audio system having a loudspeaker device, includes storing in a memory operating limits of the loudspeaker device; generating an equalization pattern; comparing the equalization pattern with the operating characteristics to determine if execution of the equalization pattern could cause the limits to be exceeded; and in the event that the execution would cause the limits to be exceeded, modifying the equalization pattern.

[0012] In another aspect of the invention, an automated process for generating an equalization pattern for an audio system, includes an initiating step, executed by a user of the audio system; a responding to the initiating step, by the audio system, wherein the responding step is selected from a predetermined plurality of responses; and generating a message to the user by the audio system, the message directing the user to perform an action.

[0013] In still another aspect of the invention, a process for generating an equalization pattern from an audio system, includes an indicating, by a user, that the user is at an intended listening location; selecting, by the audio system, of a next step, wherein the next step is selected from a plurality of possible next steps; and generating by the audio system, a message to the user, the message including the next step to be taken by the user.

[0014] Other features, objects, and advantages will become apparent from the following detailed description, when read in connection with the accompanying drawing in which:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0015]

FIG. 1 is a block diagram of an audio system according to the invention;

FIG. 2 is a diagram of a headphone for use with the invention;

FIG. 3 is a diagram of a memory for use with the invention;

FIG. 4 is a flow diagram of a process for creating an

equalization pattern according to the invention; and

FIG 5 is a block diagram of an alternate implementation of the invention.

DETAILED DESCRIPTION

[0016] With reference now to the drawing and more particularly to FIG. 1, there is shown a block diagram of an audio system according to the invention. Audio signal source 10 is coupled to audio signal processing circuitry 12 which may contain crossover circuit 24. Audio signal processing circuitry 12 is in turn coupled to loudspeaker units 14-1 - 14-6. Each of said loudspeaker units 14-1 - 14-6 includes one or more acoustic driver units, which transduce electrical signals (encoded in analog or digital form) into sound waves. Microphone device 16 is coupled to acoustic measuring circuitry 19, which is in turn coupled to equalization calculation circuitry 18 and to memory 20. Equalization calculation circuitry 18 may include microprocessor 26, and may be coupled to audio signal processing circuitry 12 and to signal source 10. Equalization calculation circuitry may also be coupled to memory 20 and may be coupled to an optional remote device 22.

[0017] Audio signal source 10 may be any of a variety of analog audio signal sources such as a radio, or, preferably, a digitally encoded audio signal source such as a CD player, a DVD or audio DVD player, or other source of digitally encoded audio signals, such as a "web radio" transmission or audio signals stored in digital form on a storage medium such as a compact disk, in random access memory, a computer hard disk or others. Audio signal processing circuitry 12 may include conventional audio signal processing elements (which can include both digital and analog components and digital to analog converters, amplifiers and others) to process the encoded audio signals which are then transduced into sound waves by loudspeaker units 14-1 - 14-6. Audio signal processing circuitry 12 may also include circuitry to decode the audio signals into multiple channels and also may include circuit elements, such as low latency infinite impulse response filters (IIRs) that can modify the frequency response of the audio system by implementing an equalization pattern developed by equalization calculation circuitry 18. Audio signal processing circuitry 12 may further include a crossover circuit 24 so that one of the loudspeaker units may be a subwoofer loudspeaker unit, while the other loudspeaker unit may be high frequency loudspeaker units. Alternatively, loudspeaker units 14-1 - 14-6 may be full range loudspeaker units without crossover circuitry, or may include both low and high frequency acoustic drivers in which case the crossover circuitry may be in the loudspeaker units 14-1 - 14-6. In still another alternative, audio signal processing circuitry 12 and loudspeaker units 14-1 - 14-6 may both include crossover circuitry that has more than one crossover frequency. For simplicity of explanation, the

invention is described with a subwoofer loudspeaker unit, a plurality of high frequency loudspeaker units, with crossover circuit 24 in audio signal processing circuitry 12 having a single crossover frequency. Loudspeaker units 14-1 - 14-6 may include one or more acoustic drivers and may also include other acoustic elements such as ports, waveguides, acoustic masses, passive radiators, acoustic resistances and other acoustic elements. Microphone device 16 may be a conventional microphone adapted to be mounted to a headband or other body mount device as will be described below. Acoustic measuring circuitry may contain elements for receiving input from microphone 16 and measuring from the microphone input a frequency response. Equalization calculation circuitry 18 may include a microprocessor and other digital signal processing elements to receive digitized signals from microphone device 16 and develop a frequency response, compare the frequency response with a desired frequency response and other information as will be described later, and develop an equalization pattern that, combined with the frequency response detected by microphone device 16 causes loudspeaker units 14-1 - 14-6 to radiate a desired frequency response. The equalization pattern may be calculated by a software program running on a microprocessor 26. The software program may be stored in memory 20, may be loaded from a compact disk playing on digital audio signal source 20 implemented as a CD player, or may be transmitted from a remote device 22, which may be an internet link, a computer, a remote digital storage device, another audio device. Alternatively, the optional remote device 22 may be a computer running a software program and transmitting information to equalization calculation circuitry 18. Memory 20 may be conventional random access memory. The audio system of FIG. 1 may be a component of a home theatre system that includes a video device, such as a television or a projector and screen.

[0018] In one operational method, a test audio signal may be played on audio signal source 10; alternatively, the source of the signal may be based on information stored in memory 20. Audio signal processing circuit 12 and loudspeaker units 14-1 - 14-6 transduce the test audio signal to sound waves which are radiated into the room about which loudspeaker units 14-1 - 14-6 are placed, characterized by a frequency response resulting from the interaction of the room with the loudspeaker units. Sound waves are received by microphone device 16 and transduced into electrical signals coupled to acoustic measuring circuitry 19. Acoustic measuring circuitry 19 measures the frequency response, and stores signals representative of the frequency response in memory 20. Equalization calculation circuitry 18 furnishes an equalization pattern signal appropriate to achieve a desired frequency response, and stores the equalization pattern signals in memory 20. Thereafter, when the audio signal processing circuitry 12 receives an audio signal from audio signal source 10, the equalization pat-

tern signal is transmitted to audio signal processing circuitry 12, which furnishes in accordance with the equalization pattern, the audio signals transmitted to loudspeaker units 14-1 - 14-6 for transduction to sound waves. In some embodiments audio signal processing circuitry 12 may contain some elements, such as digital signal processing chips, in common with equalization calculation circuitry 18 and acoustic measuring circuitry 19. In another embodiment, portions of audio signal processing circuitry 12, acoustic measuring circuitry 12, acoustic measuring circuitry 19 and equalization calculation circuitry 18 may be in a so-called "head unit" (that is, the device that contains signal sources, such as a tuner, or CD player, or connections to external signal sources, or both), and on which the controls, such as source selection and volume are located, and other portions may be on one of the loudspeaker units 14-1 - 14-6 such as a subwoofer unit, or distributed among the loudspeaker units 14-1 - 14-6. This implementation facilitates a head unit that can be used with a variety of loudspeaker systems, while the portions of the audio signal processing circuitry 12 and equalization calculation circuitry 18 that are specific to the loudspeaker system are in one of the loudspeaker units.

[0019] Additionally, the audio system of FIG. 1 may be expanded to accommodate a second set of loudspeaker units (not shown) similar to loudspeaker units 14-1 - 14-6, placed in another listening space, such as another room. The operation described in the above paragraph can then be performed in the second listening space.

[0020] Other operational methods, in addition to the operational methods described above, may be employed. In one operational method, the test signals are not radiated from all the loudspeaker units at the same time, but rather are radiated from one loudspeaker unit at time, or from a selected set of loudspeaker units to enable the separate equalization of each loudspeaker unit or of selected sets of loudspeaker units.

[0021] In another alternate operational method, the equalization pattern is stored in the form of data describing digital filters which, when applied to the audio signal, result in the desired frequency response. The data may be in the form of filter singularities or filter coefficients.

[0022] Referring now to FIG. 2, there is shown a mounting arrangement for microphone 16. Headband 28 fits on a user's head and may be adapted to hold an earpiece 30 near the ear 31 of a user. A microphone 16 may be mounted on earpiece 30. A similar microphone may be mounted on a second earpiece (not shown) positioned near another earpiece of the user. Microphone 16 may be connected to terminal 34 by electrically conductive cord 32. Terminal 34 plugs into a jack 36 which may be a bi-directional jack. Bi-directional jack 36 is in turn coupled to equalization calculation circuitry 18 and to acoustic measuring circuitry 19, not shown in this view. In other implementations, a conventional headset may be included in earpiece 30 so that in addition to

transmitting signals from the microphone acoustic measuring circuitry 19, the terminal 34 and electrically conductive cord 32 may transmit audio signals from audio signal processing circuitry 12 to earphones 30 in normal fashion. In other implementations, the microphone assembly may be implemented as one or more microphones mounted on some other portion of a headband, or on the user's body or on a stand. The jack may be adapted to fit into an auxiliary or special purpose jack and may be a one-way input jack.

[0023] Referring to FIG. 3, there is shown a diagrammatic representation of memory 20. Stored in a first portion 20-1 of memory 20 may be data signals representing characteristics of loudspeaker units 14-1 - 14-6. Such data signals may include nominal sensitivity of the loudspeaker units in their main operational band, the bandwidth of the loudspeaker units, and excursion limits of the loudspeaker units and other information. Stored in a second portion 20-2 of memory 20 may be data signals representing characteristics of crossover circuit 24. Such data signals may include cutoff frequency and nominal fall off requirements. Stored in other portions 20-6 thorough 20-n of memory may be data signals from different listening positions, the reasons for which will be explained below. Stored in other portions 20-3, 20-4, and 20-5 of memory 20 may be equalization pattern signals 1, equalization pattern signals 2, and equalization pattern signals 3, respectively. Equalization pattern signals 1, equalization pattern signals 2, and equalization pattern signals 3 may represent different equalization patterns. The several equalization patterns may be equalization patterns that are calculated using a different desired target frequency response. The several equalization patterns may also represent different "modes," for example a "party mode" in which the equalization pattern is configured to provide a pleasing frequency response throughout the listening area, or a "sweet spot" mode, in which the equalization pattern is optimized for a specific listening position. As stated above in the discussion of FIG. 2, the equalization pattern signals are stored in the form of data signals describing digital filters which, when applied to the audio signal, result in the desired frequency response. The data signals may be in the form of filter singularities or filter coefficients

[0024] The data signals representing loudspeaker units in first portion 20-1 of memory is accessible to equalization calculation circuitry 18. An example of when such data signals may be useful to the equalization calculation circuitry 18 is when a calculated equalization pattern could compromise the performance of an acoustic drive unit by damaging the unit, or by causing distortion or clipping. Rather than compromising the performance of the acoustic drive unit the equalization pattern may be modified so that the frequency response is improved over the unequalized frequency response, but without overdriving the acoustic drive unit. Additionally, the loudspeaker unit data may be useful in assessing

the integrity of the measurements. If a portion of the frequency response is below a threshold, the loudspeaker unit may not be operating properly. The data representing crossover characteristics in second portion 20-2 of memory is also accessible to equalization calculation circuitry 18. An example of the use of the data signals representing the characteristics of the crossover circuit may be when an equalization correction is necessary in the crossover band. The equalization pattern in a given frequency region that includes the crossover frequency region may be calculated such that the equalization correction is in the acoustic driver driven by the low pass section or the acoustic driver driven by the high pass section of the crossover band, or some combination of both, depending on the limitations of the drivers. Equalization pattern signals 1, 2, and 3 may be stored for later retrieval, for example, when the user desires to equalize to a different target frequency response or wishes to use a different mode as described above.

[0025] Referring to FIG. 4, there is shown a block diagram of a process for creating one or more equalization patterns according to the invention in an audio system in which the audio signal source 10 is adapted to transduce signals stored on a CD, DVD, audio DVD, or some other form of nonvolatile memory. At step 42 the process is initiated. The initiation step may include initiating a software program stored in some nonvolatile memory, which can be the same CD, DVD, audio DVD or nonvolatile memory included in signal source 10. In one implementation, the process is initiated by the user inserting a disk into audio signal source 10. The disk has stored on it a software program which includes verbal instructions, video instructions, or some combination of audio and video instructions, to the user. Following the insertion of the disk into the audio signal source 10, the software program is executed by the microprocessor 26 or by the remote device 22. At step 43, the software program reconfigures the audio system, including controlling audio parameters, such as volume, and disabling tone controls, and any time varying, nonlinear, or signal dependent signal processing. At step 44, the software program causes instructions to be communicated to the user. The instructions may be communicated to the user audibly (for example by broadcasting verbal instructions by at least one of the loudspeaker units 14-1 — 14-6 or through headphones), visually (for example by displaying words, or static or animated graphic figures on an attached video monitor, not shown), or by both verbal and visual means, which may be synchronized. The instructions may include a summary of the steps the user will be instructed to perform, as well as instructions to plug the terminal 34 into the bi-directional jack 36 or to some other input jack and to place the headband 28 on which microphones 16a and 16b are mounted, in place. The instructions may also include directions for the user to indicate when the user is ready to proceed, such as by pressing a button on the headband 28 or on a remote control unit, not shown. At step 46, the equalization cir-

cuitry performs initial acoustic tests, for example by determining if there is excessive ambient noise, and radiating a test signal and analyzing the result to ensure that both microphones are functional over the frequency band of interest and that the microphones are matched in sensitivity within a tolerance.

[0026] If the ambient noise is excessive, the user may be instructed to reduce the ambient noise. If the microphones are inoperative or not matched within a tolerance, the process may be terminated. At step 47, the user may then be instructed to move to a first desired listening location, and issue a prompt that the user is ready to proceed. At step 48, the transfer function (that is, the frequency response) at a first listening position are measured by acoustic measuring circuitry 19, and the measurements may be checked for validity, such as being within an appropriate range of amplitude, that the ambient noise is below a predetermined limit, and that the readings are within a range of coherency, stability over time, and repeatability (indicating that microphone does not move too much during the measurement). One test that can be used to test for these conditions is a linearity test. A signal is radiated and the response measured. The signal is then radiated again, scaled down by some amount, such as -3dB and the response measured and scaled up by +3dB. The scaled up response to the second signal is then compared with the response to the first signal. A significant difference may indicate that the amplitude is not within an acceptable range, that the ambient noise is above an acceptable limit, or that the readings are not coherent, stable over time, or repeatable. If there is a significant difference between the scaled up response to the first signal and the response to the first signal, at step 49, verbal or visual instructions, or both, may be broadcast to the user to instruct the user to move to a location at which the sound is within the range of amplitude or to decrease the ambient noise level, by eliminating sources of ambient noise, or to hold the microphone more still while the measurements are being taken. However, if the signal to noise ratio is too low, the system may increase the volume so that the volume is within a range of volumes, so that the signal to noise ratio is adequate, while minimizing the possibility of annoying the user or causing distortion or clipping of the radiated signal. While it is possible to measure a frequency response for the combined output of the speakers, it is generally more desirable to measure the frequency response (and thereafter calculate an equalization pattern) for each loudspeaker unit, rather than for the combined loudspeaker units.

[0027] While an equalization pattern may be calculated based on data from a single location, acquiring data from more than one location generally gives a better result. At step 52, the measurements and tests of step 48 may then be repeated for the second location, preferably for each loudspeaker unit. At the second location an additional test may also be performed, to determine whether the second location is too close to a previous

location. One method of determining if a location is too close to a previous location is to compare the frequency response at the second location with the frequency responses at the previous location. If the any of the tests, including the "closeness" test, indicate an invalid measurement, at step 53, the user may be instructed to move or make a correction as in step 49. Steps 50, 52, and (if necessary) step 53 may then be repeated for more locations. If desired, a fixed number (such as five) of locations or a minimum number (such as four) of locations or a maximum number (for example eight) of locations may be specified. If measurements have not been taken at the minimum number of locations, the user may be instructed to move to another location. If measurements have been taken at the maximum number of locations (or if measurements have been taken at the minimum number and the user indicates that measurements have been taken at all desired locations), the process proceeds to step 54. At step 54, the data signals for all the positions may be combined by the acoustic measuring circuitry 19 (by some method such as energy averaging) and an equalization pattern developed from the data signals. At step 55, an equalization pattern is calculated. At step 56, the equalization pattern may be compared with the loudspeaker unit characteristics stored in memory 20 to ascertain that no limits (such as dB of correction) are exceeded, and the equalization pattern may be modified so that the limits are not exceeded. At step 58, the filters appropriate to achieve the equalization pattern are calculated and representative signals stored for use by audio signal processing circuitry 12. As stated previously, the filters may be stored in terms of filter coefficients or filter singularities.

[0028] A software program suitable for implementing the steps of FIG 4 is included as supplementary disk A, which contains computer instructions which can be executed by a processor such as an ADSP-21065 processor, available commercially from Analog Devices Inc.

[0029] A process for creating an equalization pattern according to the invention is advantageous, because a nonexpert, untrained user can perform acoustic measurements and create equalization patterns without the use of expensive measuring and calculating equipment. Additionally, the user can easily use the apparatus and method to determine the equalization patterns for changes, such as moving the speakers, remodeling, replacing components and the like.

[0030] Referring now to FIG. 5, there is shown another embodiment of the invention, particularly suitable for audio systems for business installations such as restaurants, retail stores and the like. Several of the elements are similar to like-numbered element of FIG. 1. An audio system 60 includes an audio signal source 10. Audio signal source 10 is coupled to audio signal processing circuitry 12 which may contain crossover circuit 24. Audio signal processing circuitry 12 is in turn coupled to loudspeaker units 14-1 - 14-n. Each of said loudspeaker units 14-1 - 14-n includes one or more acoustic driver

units, which transduce electrical or digital signals into sound waves. A portable computer device 62 includes a microphone device 16 coupled to acoustic measurement circuitry 19. Acoustic measurement circuitry 19 may be coupled to equalization calculation circuitry 18, which may be coupled to microprocessor 26. Microprocessor 26 is in turn coupled to memory 20. Audio system 60 and portable computer device 62 are adapted so that equalization patterns determined by equalization calculation circuitry 18 can be downloaded to audio signal processing circuitry 12 as indicated by broken line 64.

[0031] Microphone device 16 may be a conventional microphone adapted to be attached to, or mounted on, a portable computer device. Acoustic measuring circuitry may include devices for measuring a frequency response. Equalization calculation circuitry 18 may include a microprocessor and processing elements to compare the measured frequency response with a desired frequency response and other information as will be described later, and develop an equalization pattern that, combined with the frequency response detected by microphone device 16 causes loudspeaker units 14-1 - 14-6 to radiate a desired frequency response. In one embodiment, equalization calculation circuitry 18 is implemented as a software program which run on microprocessor 26. The software program may be stored in memory 20, which may be conventional random access memory, or some other form of computer memory such as flash memory or ROM.

[0032] In operation, a test audio signal may be played on audio signal source 10. In one implementation, the test tone is recorded on a CD that has a continuous audio track with a 50% duty cycle of silence interspersed with bursts of test tones. In other implementations, the test tone may be stored in memory 20 or in some other component of portable computer device 62. Audio signal processing circuit 12 and loudspeaker units 14-1 - 14-6 transduce the test audio signal to sound waves which are radiated into the room about which loudspeaker units 14-1 - 14-6 are placed, characterized by a frequency response resulting from the interaction of the room with the loudspeaker units. Microphone 16 is moved to an appropriate position in the room and triggered. Microphone device 16 transduces the next burst of the test tone, and acoustic measurement circuitry 19 determines frequency response for that position. Microphone device 16 is then moved to a second position, and the transduction and frequency response determination is repeated. After an appropriate number of measurements, a software program loaded into, or residing on, portable computer device 62, determines an average room response from the position responses, and determines an equalization pattern appropriate to achieve a desired frequency response, and stores the equalization pattern signals in memory 20. Thereafter, the equalization pattern signals are downloaded from portable computer device 62 to audio signal processing circuitry 12, which furnishes in accordance with the

equalization pattern the audio signals transmitted to loudspeaker units 14-1 - 14-6 for transduction to sound waves.

[0033] In another implementation, rather than triggering the portable computer device 16 at each location, the portable computer device is moved about the room, and a frequency response is determined for each tone burst. The frequency responses corresponding to each tone burst are continuously averaged to determine the room frequency response.

[0034] In still another implementation, computer device 62 has stored on it a plurality of different selectable equalization targets corresponding to different listening conditions. Different listening conditions might include foreground music vs. background music; different types of music; noisy vs. quiet environments; different ambiences. The equalization pattern determined by equalization circuitry 18 will then be the difference between the room frequency response and the selected equalization target.

[0035] An audio system according to the embodiment of FIG. 5 is particularly advantageous for situations in which an audio system is designed and installed by a professional audio system designer for use in a commercial establishment, such as a restaurant, lounge, retail store, mall, and the like. For these situations, the audio system does not require a microphone or any equalization calculation circuitry. The equalization calculation circuitry and the microphone device may be included in a portable computer device 62 which can be used for a number of different installations.

[0036] It is evident that those skilled in the art may make numerous modifications of and departures from the specific apparatus and techniques disclosed herein without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in or possessed by the apparatus and techniques disclosed herein and limited solely by the spirit and scope of the appended claims.

Claims

1. An equalising system for developing equalization patterns for an audio system comprising a source of audio signals, signal processing circuitry coupled to said source for processing said audio signals to produce processed audio signals, a plurality of loudspeaker units, coupled to said signal processing circuitry, constructed and arranged to be deployed about a room, for radiating sound waves responsive to said processed audio signals, said equalising system comprising:

acoustic measuring circuitry, including a microphone unit, for receiving and transducing said sound waves and for providing signals repre-

- sentative of frequency responses at a plurality of locations;
a memory, coupled to said acoustic measuring circuitry, for storing said signals representative of frequency responses at said plurality of locations; and
equalisation calculation circuitry, responsive to said signals representative of frequency responses at a plurality of locations, for providing an equalisation pattern signal.
2. An equalizing system in accordance with claim 1, wherein said equalization calculation circuitry responsive to said signals representative of frequency response at said plurality of locations, for providing an equalization pattern signal.
 3. An equalizing system in accordance with claim 1 or claim 2, wherein said signal processing circuitry and said equalization calculation circuitry share circuit elements.
 4. An equalizing system in accordance with any of claims 1 to 3, wherein the coupling path between said microphone unit and said acoustic measuring circuitry comprises electrically conductive wire free of wireless portions.
 5. An equalizing system in accordance with any of claims 1 to 4, wherein the coupling path between said microphone unit and said equalization calculation circuitry comprises a bi-directional jack.
 6. An equalizing system in accordance with any of claims 1 to 5, further comprising crossover circuitry coupling said signal processing circuitry and said plurality of loudspeaker units,
wherein said memory is further for storing characteristic data signals representative of said crossover circuitry, and wherein said equalization calculation circuitry is further for furnishing an equalization pattern signal responsive to said characteristic data signals representative of said crossover circuitry.
 7. An equalizing system in accordance with any of claims 1 to 6, wherein said microphone unit is constructed and arranged to be mounted on a device that is mountable on a user's body.
 8. An equalizing system in accordance with claim 7, wherein said body mountable device is a headband.
 9. An equalizing system in accordance with any of claims 1 to 8, wherein said microphone unit comprises a plurality of microphones.
 10. An equalizing system in accordance with any of claims 1 to 9, wherein said equalization calculation circuitry is constructed and arranged to determine an equalization pattern that is substantially continuous with regard to frequency.
 11. An equalizing system in accordance with any of claims 1 to 10, wherein said equalization calculation circuitry comprises a microprocessor running a software program.
 12. An equalizing system in accordance with any of claims 1 to 11, wherein said equalization calculation circuitry comprises a link to a remote memory for storing said software program.
 13. An equalizing system in accordance with any of claims 1 to 12, wherein said microprocessor is physically remote from said equalization calculation circuitry.
 14. An equalizing system in accordance with any of claims 1 to 13, wherein said software program comprises code for causing audible instructions for said user to be radiated by at least one of said plurality of loudspeaker units.
 15. An equalizing system in accordance with any of claims 1 to 14, said audio system further comprising a video device, wherein said software system comprises code for causing visual instructions for said user to be displayed by said video device.
 16. An equalizing system in accordance with any of claims 1 to 15,
wherein said microphone unit is adapted to be moved about said room to a plurality of positions, to transduce said sound waves received at each of said plurality of positions to produce a corresponding plurality of sets of frequency response measurement signals;
wherein said memory is further for storing said plurality of sets of frequency response measurement signals;
and wherein said equalization calculation circuitry is further for providing an equalization pattern signal responsive to said plurality of sets of frequency response measurement signals.
 17. An equalizing system in accordance with claim 16, wherein said equalization pattern signal is representative of the energy average of said frequency response measurements.
 18. An equalizing system in accordance with any of claims 1 to 17, wherein said audio processing circuitry comprises low latency filters.
 19. An equalizing system in accordance with any of

- claims 1 to 18, wherein at least one of said plurality of loudspeaker units comprises a plurality of acoustic driver units, and wherein said memory is further for storing characteristic data signals representative of said acoustic driver units.
20. An equalizing system in accordance with any of claims 1 to 19, wherein said equalization calculating circuitry is constructed and arranged to control an operating parameter of said audio system.
21. An equalizing system in accordance with claim 20, wherein said operating parameters include at least one of volume setting and tone setting.
22. An equalizing system in accordance with claim 20, wherein said equalizing calculating circuitry is constructed and arranged so that said equalizing calculating circuitry has exclusive control over said operating parameter and so that user accessible controls of said operating parameters are disabled.
23. An equalizing system in accordance with any of claims 1 to 22, wherein said audio system is constructed and arranged to broadcast verbal instructions for operating said audio system to a user.
24. An equalizing system in accordance with any of claims 1 to 23, wherein said equalization calculation circuitry is constructed and arranged to provide said signals representative of frequency responses at said plurality of locations for each of said loudspeaker units singly.
25. An equalizing system, in accordance with any of claims 1 to 24,
 wherein said memory is further for storing characteristic data signals representative of said loudspeaker units; and
 where said equalization calculation circuitry is further for providing said equalization pattern signal responsive to said characteristic data signals representative of said plurality of loudspeaker units.
26. An equalizing system in accordance with any of claims 1 to 25,
 wherein said equalization pattern signal is representative of the energy average of said frequency responses at said plurality of locations.
27. An audio system, comprising:
 a source of audio signals;
 signal processing circuitry coupled to said source for processing said audio signals to produce processed audio signals;
 a plurality of loudspeaker units, coupled to said signal processing circuitry, constructed and arranged to be deployed about a room, for radiating sound waves responsive to said processed audio signals;
 a microphone unit, for receiving said sound waves and for transducing said sound waves to electrical signals;
 acoustic measuring circuitry, for receiving said electrical signals and providing frequency response signals;
 and an equalisation system according any of claims 1 to 26.
28. An audio system, comprising:
 a storage medium for storing digitally encoded information signals;
 signal processing circuitry coupled to said storage medium to produce audio signals;
 a plurality of loudspeaker units, coupled to said signal processing circuitry, constructed and arranged to be deployed about a room, for radiating sound waves responsive to said audio signals;
 a microphone unit, for receiving said sound waves and transducing said sound waves to electrical signals; and
 a microprocessor electronically coupled to said storage medium and to said microphone, for providing an equalization pattern signal responsive to said electrical signals; wherein said digitally encoded information signals includes digitally encoded signals representing instructions to a user.
29. An audio system in accordance with claim 28, wherein said storage medium is a compact disk.
30. An audio system in accordance with claim 28 or claim 29, wherein said digitally encoded information signals further includes an encoded computer program for generating an equalization pattern signals.
31. An audio system in accordance with claim 30, wherein said computer program controls parameters of said audio system.
32. An audio system in accordance with claim 28, wherein said digitally encoded information signals represent audio signals representing audible instructions for said user.
33. An audio system in accordance with any of claims 28 to 31, said audio system further comprising a video display device, wherein said digitally encoded information signals represent video signals representing instructions for said user, said instructions displayable on said video display device.

34. A process for generating an equalization pattern for an audio system having a loudspeaker device and a microphone, said audio system operating in a listening space, said process comprising:

a first positioning said microphone at a first location;
 a first radiating, by said loudspeaker device, of a sound wave;
 a first receiving, by said microphone, of said sound wave;
 responsive to said receiving, a first measuring of a first frequency response of said audio system;
 a second positioning said microphone at a second location;
 a second radiating, by said loudspeaker device, a sound wave;
 a second receiving, by said microphone said sound wave;
 responsive to said second receiving, a second measuring of a second frequency response of said audio system;
 comparing said first frequency response with said second frequency response to determine the difference between said first frequency response and said second frequency response;
 and
 in the event that said difference is less than a predetermined amount, generating a message.

35. A process for generating an equalization pattern signal in an audio system having a first microphone and a loudspeaker unit, comprising:

testing, by said audio system, said microphone to determine if said microphone is functional over a frequency range; and in the event said microphone is not functional over said frequency range, generating a message to a user.

36. A process for generating an equalization pattern in an audio system in accordance with claim 34 or 35, wherein said message is radiated as sound waves from said loudspeaker unit.

37. A process for generating an equalization pattern in an audio system in accordance with claim 34, wherein said audio system comprises a second microphone, further comprising:

testing whether said second microphone and said first microphone are matched within a predetermined tolerance; and
 in the event that said first microphone and said second microphone are not matched within said predetermined tolerance, generating a message to said user that said first microphone

and said second microphone are not matched.

38. A process for generating an equalization pattern in an audio system operating in a listening area, said listening area having an ambient noise level, said process comprising:

radiating a sound at an amplitude into said listening area;
 measuring, by said audio system, the signal to noise ratio in said listening area; and
 in the event that said signal to noise ratio is below a predetermined threshold ratio, increasing said signal to noise ratio.

39. A process for generating an equalization pattern in an audio system in accordance with claim 38, wherein said increasing signal to noise ratio includes the step of instructing a user to decrease said ambient noise.

40. A process for generating an equalization pattern in an audio system in accordance with claim 38, wherein said increasing signal to noise ratio includes the step of increasing said amplitude of said radiated sound.

41. A process for generating an equalization pattern in an audio system in accordance with claim 38, the system being further provided with a microphone, and the process further comprising:

receiving, by the microphone, said sound wave;
 measuring the amplitude of said received sound wave to determine if said amplitude is within a predetermined range of amplitudes;
 and
 in the event that said amplitude is not within said predetermined range of amplitudes, changing said amplitude so that said amplitude is within said predetermined range.

42. A process for generating an equalization pattern in an audio system in accordance with claim 41, wherein said amplitude is increasable by an equalization calculation circuit and is not increasable by a user.

43. A process for generating an equalization pattern in an audio system in accordance with any of claims 34 to 36, wherein said message directs a user to move to a different location.

44. A process for generating an equalization pattern for an audio system having a loudspeaker device, comprising:

storing in a memory operating limits of said

loudspeaker device; generating an equalization pattern signal;
 comparing said equalization pattern signal with
 said operating limits to determine if execution
 of said equalization pattern signal could cause
 said operating limits to be exceeded; and
 in the event that said execution would cause
 said limits to be exceeded, modifying said
 equalization pattern signal.

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45. An automated process for generating an equalization pattern signal for an audio system, comprising:

an initiating step, executed by a user of said audio system;
 a responding to said initiating step, by said audio system, wherein said responding step is selected from a predetermined plurality of responses; and
 generating a message to said user by said audio system, said message directing said user to perform an action.

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46. An automated process for generating an equalization pattern signal for an audio system in accordance with claim 45, wherein said generating includes radiating through said loudspeaker units, a message to said user.

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47. An automated process for generating an equalization pattern signal for an audio system in accordance with claim 45 or claim 46, wherein said initiating step comprises placing a compact disk in a compact disk player.

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48. A process for generating an equalization pattern for an audio system in accordance with claim 45, wherein said initiating step causes said audio system to be reconfigured.

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49. A process for generating an equalization pattern for an audio system, comprising:

an indicating, by a user, that the user is at an intended listening location; selecting, by said audio system, of a next step, wherein said next step is selected from a plurality of possible next steps; and
 generating by said audio system, a message to said user, said message including the next step to be taken by the user.

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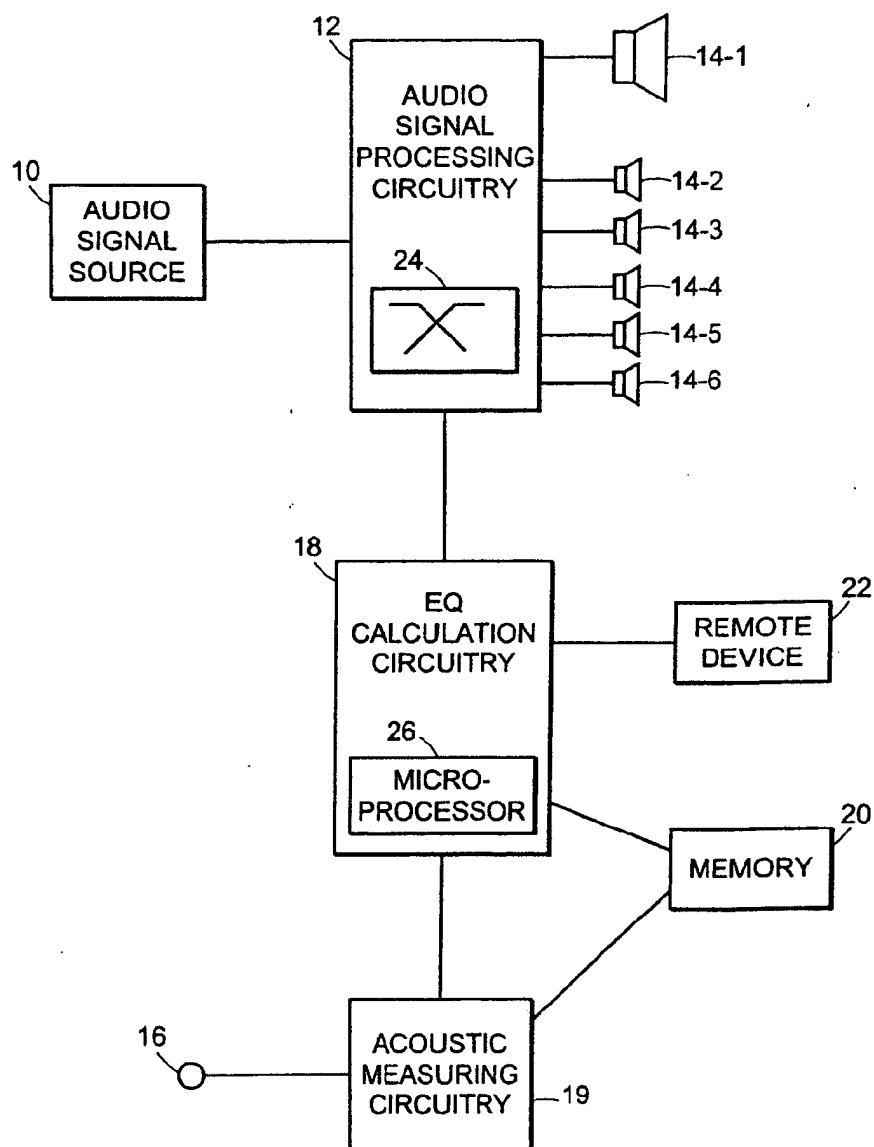


FIG. 1

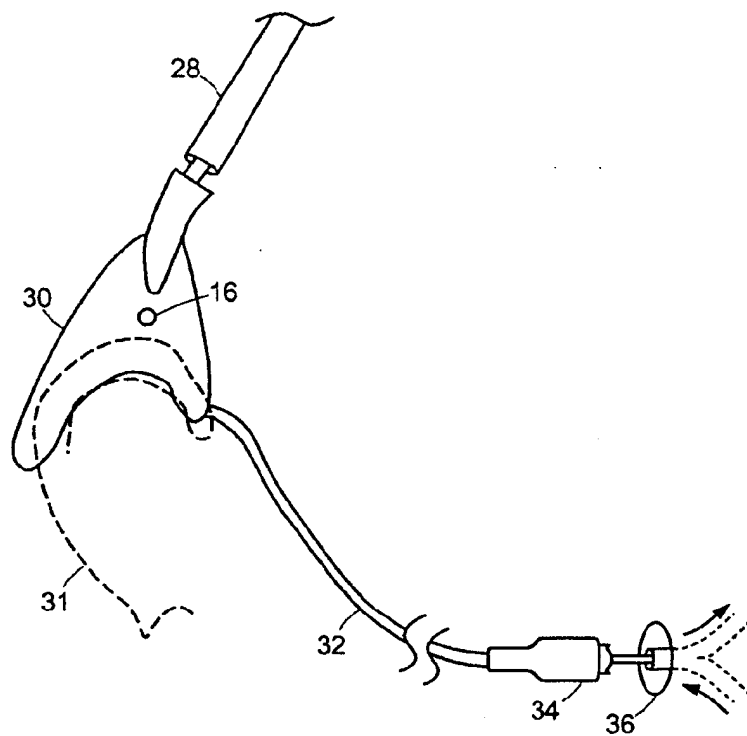


FIG. 2

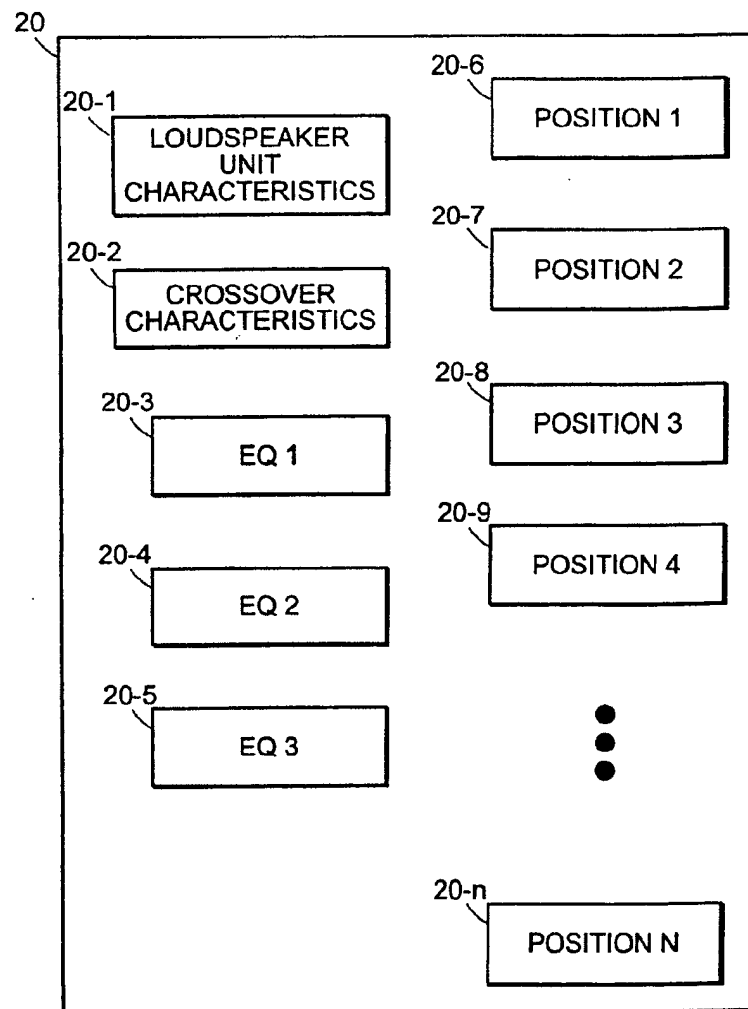


FIG. 3

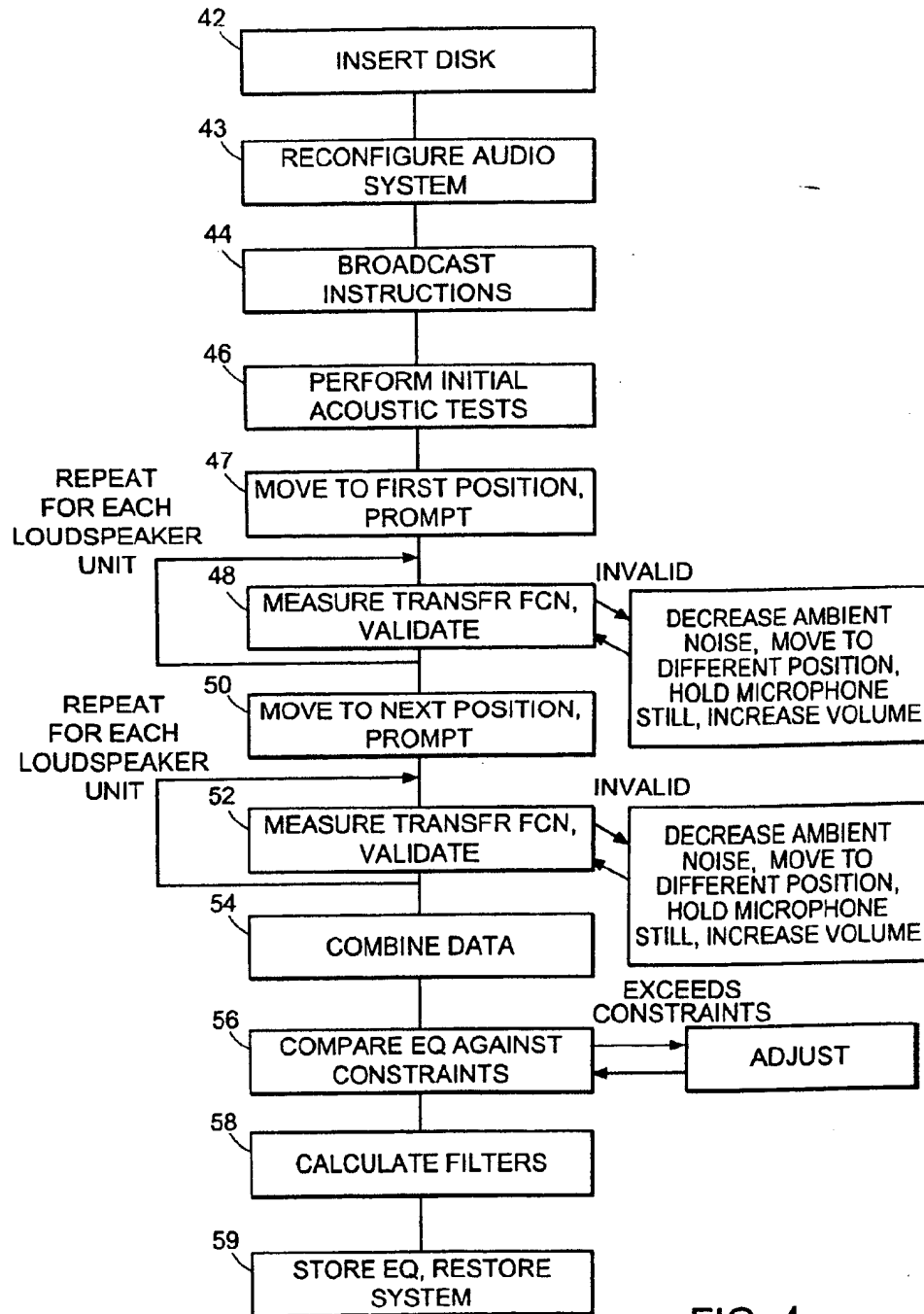


FIG. 4

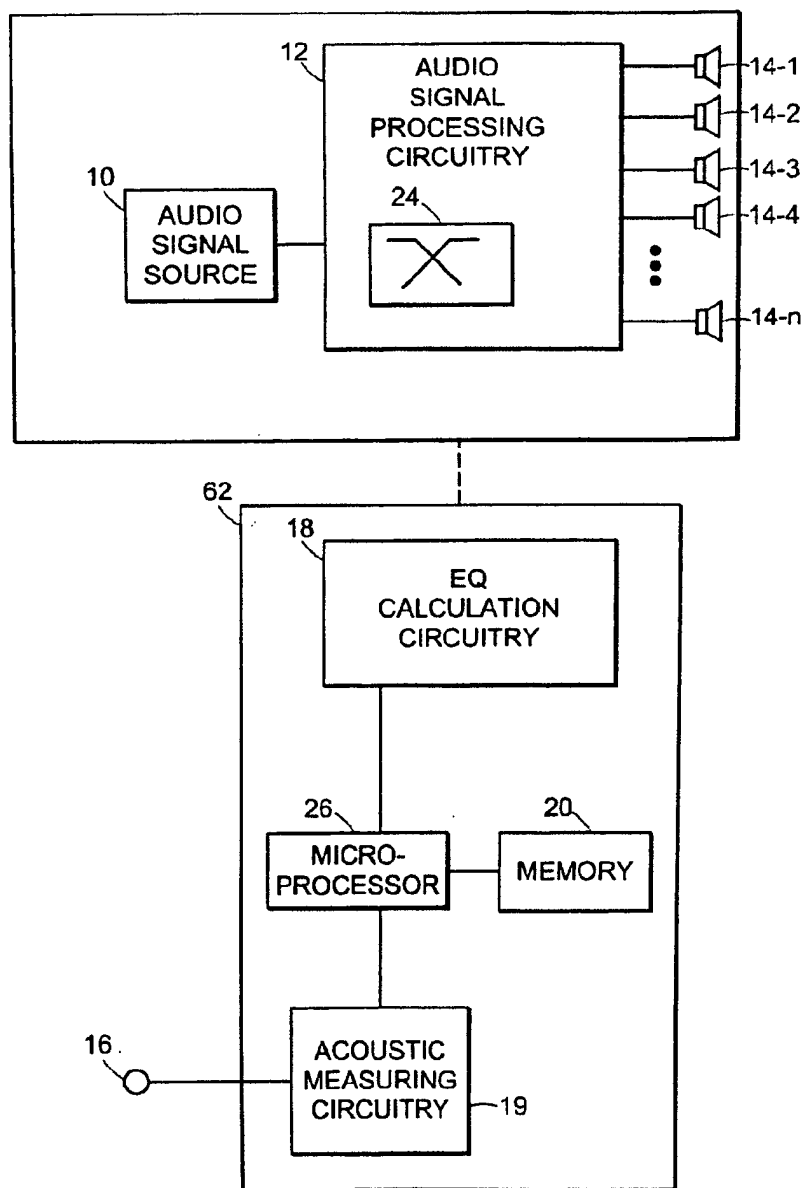


FIG. 5



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(54) **Automatic audio equalising system**

(57) An automated process for equalizing an audio system and an apparatus for implementing the process. An audio system includes a microphone unit, for receiving the sound waves radiated from a plurality of speakers, acoustic measuring circuitry, for providing frequency response measurement signals; a memory, for storing characteristic data signals representative of the loudspeaker units and further for storing the frequency response measurement signals; and equalization calculation circuitry, for providing an equalization pattern signal responsive to the frequency response measurement signals and responsive to the characteristic data signals representative of the plurality of loudspeaker units. Also described is an automated equalizing system including acoustic measuring circuitry including a microphone for providing frequency signals representative of responses at a plurality of locations; a memory, for storing the signals representative of frequency responses at the plurality of locations; and equalization calculation circuitry responsive to the signals representative of the frequency responses for providing an equalization pattern signal.

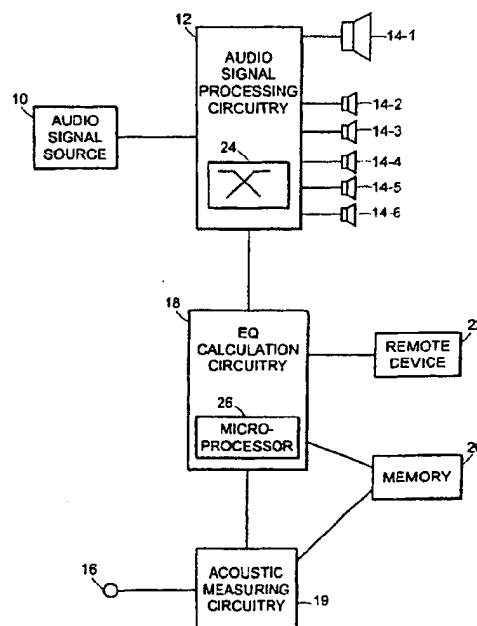


FIG. 1



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